Individual differences in task performance under conditions of cognitive interference[1]

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It has been suggested that most experiments on psychological stress can be divided into studies of "failure-induced" and "task-induced" stress (12) Failure-induced stress (or, as we shall hereinafter refer to it, *ego-threatening stress*) occurs when the subject perceives certain of his ego strivings as thwarted or potentially thwarted For example, he feels he is not doing as well as expected of him Task-induced stress, on the other hand, does not threaten the individual's integrity; rather it refers to a direct interference with the subject's cognitive functioning by such techniques as distraction, interference, or time pressure

The study reported here concerns the latter type of stress which we shall hereinafter refer to as *cognitive-interference stress* The general findings in the area of cognitive-interference stress include evidence that such stress may result in both increments and decrements of performance (**1**, **8**), increases in the expenditure of enegry (**3**, **4**, **7**, **16**, **17**), and feelings of tension and unrest (**20**) It seemed to us that these types of findings might be interpreted through the use of cognitive theory, such as described by Scheerer (**21**), in a way compatible with concepts previously suggested by Lazarus and Baker (**10**) in their theoretical framework for the problem of psychological stress Accordingly, the following assumption was made

> An organization of psychological processes regulating a given class of tasks (hereinafter, a cognitive subsystem which involves general tendencies of cognitive functioning) has an inherent tendency to maintain its organization in the face of interfering stimuli[2]

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[1] This investigation was supported by research grant (M-734) from the National Institute of Mental Health, Public Health Service

[2] It should be noted, parenthetically, that this idea has formal similarity to the propositions of the organismic personality theorists such as Rogers (**20**), Lecky (**14**), and Goldstein (**5**), in their emphasis on self-systems tending to maintain or enhance themselves

From this assumption, it seems reasonable to derive the following hypotheses·

1 The stronger the tendency of a cognitive subsystem to maintain itself (stronger organization), the less likely it is to be impaired by distraction
2 Of two competing cognitive subsystems, the one with the stronger tendency to maintain itself will tend to dominate behavior at the expense of the weaker organization

Thus, strong cognitive subsystems, under certain conditions at least, ought to have directive effects upon behavior The experiments which we shall report here were designed to deal with these hypotheses

A critical methodological problem at this point is the measurement of the strengths of organization of cognitive subsystems, which may then be used to predict stability of performance under stressor conditions An interpretation of some almost completely neglected past research seemed to offer a possible solution to this problem

It has been long known that the literate adult is able to read the names of colors faster than he is able to name colors themselves In the nineteen-thirties Stroop (**23**) argued that the reason for this was that people tended to practice giving verbal responses to words more than they practiced giving such responses to colors Stroop (**23**) also showed that the same effects are obtained if the rates of reading names of common objects are compared with the rates of naming such objects At about this time Ligon (**15**) demonstrated that while both of these speeds (color naming and color name reading) increase with advancing age and education, the speed of reading names of colors increases relatively faster Stroop (**24**) maintained that this was consistent with his practice argument since as we grow older and are more educated we tend increasingly to employ abstract language, either written or spoken, while the same is not true of our tendency to go about naming specific objects

In our own work with the Stroop test, we have noticed that considerable individual differences exist, within a given age group, in the ratio of the performance speeds of the two tasks (color naming and color name reading) In line with Stroop's arguments, these differences are interpretable as indicating differing amounts of practice which different individuals have devoted to the two types of function Accordingly, we might employ our notion of the stronger cognitive subsystem dominating weaker competing subsystems, and argue that the differential amounts of practice occurred because of differential strengths of the respective cognitive subsystems Castaneda and Palermo (2), from an associative learning point of view, would prefer to say that the differences in practice have resulted in differential habit strengths for the two tasks, thus giving rise to different speeds of response From either theoretical framework, however, it seems reasonable to interpret the ratio of color naming speed to color name reading speed as an index of the present relative strengths of the respective cognitive subsystems Accordingly, on the basis of the inference from this ratio of differential strengths of the two general cognitive subsystems in different *S*s, we can predict the degree of resistence to distraction or interference for these *S*s on any task relevant to the respective subsystems

The nature of these cognitive subsystems was suggested by previous researches of our own Thus, if we designate *S*s who are relatively facile in reading the names of colors as "conceptual" and those *S*s who are relatively more facile in naming colors as "sensorimotor" oriented, we found that conceptual *S*s appear to have little interest in sensorimotor tasks, compared with the so-called sensorimotor *S*s For example, in one study comparing the two kinds of individuals, we had the *S*s paint simple geometric designs and found that the "conceptual" group performed much more rapidly and carelessly, completing the task in half the time of the sensorimotor *S*s, and making twice as many errors (missing or going over the contour lines of the designs) In other studies which have been reported (**11**, **13**) both conceptual and sensorimotor *S*s were required to listen to recorded paragraphs and write down "what they heard" Under these relatively ambiguous instructions, the conceptual *S*s paraphrased the content of the passages, getting the essential ideas, while the sensorimotor *S*s performed the task by literally writing down, in a perceptual fashion, each word of the passage

Our first hypothesis, that the stronger the cognitive subsystem, the less impairment in the relevant task performance there will be under distraction, was tested by comparing how rapidly and effecttively *S*s solved addition problems under neutral and distracting conditions Since arithmetic problems have been described as "one of the purest forms of abstract thinking" (**18**, p 199), the prediction was made that conceptual *S*s would show less impairment on that type of cognitive function under distraction than sensorimotor *S*s

The second hypothesis (that of two competing cognitive subsystems the one with the stronger organization would tend to dominate behavior at the expense of the weaker subsystem, thus exerting a directive effect upon behavior), was tested by examining the simultaneous performance of two tasks (interference condition) compared with performances on each task alone One task was conceptual in nature (addition problems), the other sensorimotor in character (disjunctive serial reaction time) We made the prediction that the conceptual *S*s would favor the addition problems under the interference condition at the expense of reaction time, and, conversely, that the sensorimotor *S*s under the interference condition would show more impairment on the addition problems than on reaction time

PROCEDURE

Eightly male Clark University undergraduates were given a modified form of the Stroop Color Word Test This test presents three tasks to the *S*s (*a*) to read aloud as quickly as possible three color names (red, green, and blue) which are printed on a white card in black ink a total of 100 times in random order, (*b*) to identify correctly as quickly as possible by color name 100 colored rectangles of the same three hues and in the same sequences as in the first card, and (*c*) to name as quickly as possible the color of the ink (red, green, or blue) in which 100 color names (red, green, and blue) are printed where the color name and the hue of the ink are always incongruent —e g , the word "blue" might be printed in red ink, the word "green" in blue ink, etc

Out of this total group of eighty *S*s, twelve clearly conceptual and twelve clearly sensorimotor *S*s were selected on the basis of the ratios of speed of color naming to speed of color name reading For the concepual *S*s these ratios ranged from 1 42 to 2 13 with a median ratio of 1 55 For the sensorimotor *S*s, the range was 1 31 to 1 12 with a median ratio of 1.25 The two groups of *S*s were matched for their absolute speeds on the first and third cards of the Stroop Color Word Test

The addition problems were grouped into two classes, "simple" and difficult " Simple problems consisted of two numbers whose sum ranged from two to eight Difficult problems consisted of two numbers whose sum ranged from twenty-eight to forty-nine In the analysis of data, all the addition problems, simple and difficult, have been combined since there was no significant effect of this classification

Also, the addition problems were presented to the *S*s in two modalities, visual and auditory The results of both modalities have been combined because there was no significant effect produced by mode of presentation Two trials were given in each modality The score was the number of problems solved correctly up to the point where the *S* last had three successive problems correctly answered

In the visual presentation, the *S* was given a sheet of paper containing

100 problems, and was told to write the answers to as many of the problems as possible within a one-minute period Such a minute period constituted one trial and the score for the trial was the number of problems answered correctly in that time

The auditory presentation involved the use of a tape recorder and earphones The problems had previously been recorded at a pre-established schedule of rates of delivery, starting slowly but increasing every ten seconds Earphones were placed upon the *S* and he was told that when the recorder was turned on, he would hear the experimenter's voice reading arithmetic problems His task was to write down the answers to the problems and he was told, in advance, that at first he would have little difficulty keeping up with the voice, but that the pace would gradually increase until it became quite rapid He was not to give up if he missed a few problems

The serial disjunctive reaction time included three colored lights—red, green, and blue—located in front of the *S*'s nonpreferred hand In front of each light was a similarly colored key The lights were automatically illuminated according to one of three predetermined schedules A timer was activated whenever a light was illuminated The *S* was instructed to extinguish the light as fast as possible by placing his hand on the like colored key He was told to keep his hand upon the key until the next light flashed on Premature release of the light would re-illuminate the light since there was always, potentially, one light on A single trial on this task consisted of nine lights presented in a one-minute period The *S*'s score for that trial was the total time that the lights remained illuminated in the one-minute period

In the test of our first hypothesis, the addition problems were performed under two conditions, a neutral or control condition without distraction, and an auditory distraction condition which consisted of a tape recording of a female voice reading numbers similar to those presented in the experimental arithmetic task The rate of delivery of the distraction voice was initially slow but increased every ten seconds In both the visual and auditory presentation of the arithemtic task, the distraction stimuli were presented to the *S* through earphones

In the test of our second hypothesis, the same *S*s were used and both the arithmetic task and the reaction time task were first performed separately in a control condition This condition included four trials on the arithmetic problems (two in each modality) and five trials on the reaction timer The best of the five trials on the reaction time task was taken as representative of *S*'s optimum performance on this task The experimental interference condition involved presentation of both tasks to the *S* for simultaneous performance There were four trials in this condition, two with addition problems visually presented, two with addition problems audibly presented The *S* was instructed to do the best job possible on both tasks at the same time

The sequence of tasks, which was the same for all *S*s, was as follows

1 Control simple visual addition problems
2 Distraction simple visual addition problems
3 Control difficult visual addition problems
4 Distraction difficult visual addition problems
5 Control simple audible addition problems

6 Distraction simple audible addition problems
7 Control difficult audible addition problems
8 Distraction difficult audible addition problems
9 Control serial disjunctive reaction time
10 Interference reaction time *vs* simple visual addition problems
11 Interference reaction time *vs* difficult visual addition problems
12 Interference reaction time *vs* simple audible addition problems
13 Interference reaction time *vs* difficult audible addition problems

RESULTS

Statistically significant differences between the two groups (conceptual and sensorimotor) were not found in the control condition on either task, although there were slight advantages for the conceptual *S*s on the addition problems and for the sensorimotor *S*s on the reaction time task As was anticipated, high correlations were found between the control and the distraction and interference stress performances Regression equations of each stress performance on the control performances were, therefore, calculated, and the deviations from the values predicted by the regression coefficient were used as the dependent variables This technique, in effect, controls for differences in the initial abilities of the *S*s These deviations were then converted into *t* scores with a mean of 50 and a sigma of 10

A comparison of the results of the conceptual and sensorimotor groups on addition problems under the distraction condition is presented in Table 1 As hypothesized, the conceptual *S*s are significantly less impaired under distraction on the arithmetic task than the sensorimotor *S*s

TABLE 1

ARITHMETIC PERFORMANCE UNDER DISTRACTION STRESS AS A FUNCTION OF COGNITIVE ORGANIZATION[a]

	Mean *t* Score	*df*	*F*	*p*
Conceptual Group	46 79	22	9 11	< 01
Sensorimotor Group	52 69			

[a] A low score indicates less impairment due to stress

There is also some suggestion that distraction facilitated the performance of some *S*s and impaired the performance of others as a function of the relation between the task and the cognitive subsystem If we examine the total percentage change in performance from the control to the distraction condition, 14 *S*s showed improvement while ten showed decrement A breakdown on the basis of the conceptual-sensorimotor dichotomy suggests that more conceptual *S*s improved their performance while more sensorimotor *S*s showed impairment under distraction However, the chi-square analysis of these data does not reach statistical significance (see Table 2)

TABLE 2

DIRECTION OF CHANGE IN ARITHMETIC PERFORMANCE UNDER DISTRACTION AS A FUNCTION OF COGNITIVE ORGANIZATION

	Number of *S*s with Improved Performance	Number of *S*s with Impaired Performance
Conceptual Group	9	3
Sensorimotor Group	5	7

Chi-square equals 2 74 *p* value between 15 and 10 level of confidence

In the interference condition, we compared the disruptive effects in the two groups resulting from simultaneous performance of two tasks where one task is sensorimotor in emphasis and the other more conceptual As before, regression equations were based upon the initial control performances on each task and the results are presented in terms of *t*-score deviations from the predicted values Table 3 presents the results of the interference stress condition in which the two tasks—addition problems and reaction time—were performed simultaneously Examination of Table 3 shows that the conceptual group was less impaired on the addition problems and more impaired on the reaction time task than the sensorimotor group The interaction by means of analysis of variance is significant at the 02 level of confidence Again, we see that where the task operations

TABLE 3

PERFORMANCE UNDER INTERFERENCE STRESS AS A FUNCTION OF COGNITIVE ORGANIZATION[a]

	Mean *t* Score Addition Problems	Mean *t* Score Reaction Time	*df*	*F*	*p*
Conceptual Group	48 50	54 00	22	6 85	< 02
Sensorimotor Group	52 00	48 60			

[a] A low *t* score indicates less impairment due to stress

involve a strong cognitive subsystem, the disruptive effects on that task of interference stress are minimal From a slightly different perspective, in this situation, which tends to produce a sacrifice of effectiveness of performance on one task in favor of another, the conceptual *S*s might be seen as directing more of their efforts towards the abstract task of addition problems, while the sensorimotor *S*s resolved the competition of tasks by orienting themselves more to the sensorimotor task

Discussion

The proposition that cognitive subsystems have inherent tendencies to maintain themselves has enabled us to predict individual differences in the stability of performance under conditions of distraction The notion that strong cognitive subsystems will influence behavior has permitted us to predict directedness in behavior in an interference situation

In this paper, we have attempted to infer two possible cognitive subsystems, conceptual and sensorimotor, each of which includes a large variety of task operations that may be of interest and importance in adaptive behavior However, in the present state of our research, relatively little is known of the exact nature, limits, or origins of these subsystems Also, there are undoubtedly other subsystems, all of which will eventually require theoretical integration In this respect, the subsystems described in this paper are on a par with other empirically derived cognitive dimensions that have been discussed in the recent literature—e g , Klein (9), Schlesinger (22), Witkin (25), and Gomulicki (6)

Despite these limitations, the notions of cognitive interference stress and cognitive organization which we have dealt with here can be usefully added to and integrated with the motive-thwarting conception of psychological stress presented by Lazarus and Baker (10) Motive thwarting, according to these authors, results in affective arousal, which, in turn, elicits regulative mechanisms aimed at reducing or managing the affect Ego defenses such as repression or intellectualization may be considered as one type of regulative mechanism Another type has been loosely referred to (9, 10) as "cognitive controls or styles," which are, in a sense, also broad cognitive subsystems which orient the person toward stimuli in particular ways

Often implicit in these separate concepts of cognitive control and ego-defense is the notion that they are parallel or even identical in structure, but manifested in different ways or under different conditions, although this possibility has not been very well clarified theoretically or empirically It is possible, for example, that the sensorimotor orientation is found in the same person who manifests a tendency to cope with threat by means of repression, viz , the hysterical character), while the conceptual cognitive subsystem is associated with the intellectualization and isolation defenses of the obsessive character It is very likely that many of the current typologies which have cognitive implications (e g , inner directed–other directed, body dependent–field dependent, extrovert–introvert, leveler–sharpener, ideational–motoric, anal–phallic, etc) are dealing with common cognitive subsystem dimensions while using different terminology or emphasizing different psychological contexts

To return to the integration of cognitive subsystems with the problem of stress and adaptation, if affect is thought of as an internal interfering stimulus which tends to disorganize cognitive processes (just as distraction or interference tends to), then its effect should depend, in part, upon the strength of the cognitive subsystem related to the task requirements as well as the degree of affect (the strength of the internal stimulus) The degree of this affect which is free to impinge on cognition may depend upon the type and effectiveness of regulatory mechanisms such as ego defenses (it can mobilize defenses, or be utilized in the adaptive task itself), but its effect on cognitive performance will be related to the strength of the cognitive subsystem which is relevant to the adaptive task on hand

One final point of a more methodological nature arises out of the present research On the basis of our obtained results, the concept of general traits such as distractibility, stress tolerance, etc , ought to be considerably qualified The effects on performance of distraction or interference must be considered in relation to the nature of the tasks being performed and in relation to the cognitive characteristics of the subjects performing them For example, had we generalized just from the initial distraction experiment, we would have had to argue that conceptual *S*s are less prone to distraction than sensorimotor *S*s However, that this is not a completely general trait including all kinds of tasks is suggested by the conceptual *S*s greater impairment on the reaction time task in the second experiment under interference stress Therefore, the effects of interference stressor conditions cannot be studied meaningfully as main effects independent of the cognitive characteristics of the *S*s involved and of the task operations which must be performed This latter point may explain why different experiments employing distraction have produced such dissimilar results, some demonstrating impairment and others facilitation Whether or not impairment or facilitation will take place probably depends upon the complex three-way relationship between the nature of the interference or distraction, the cognitive structure of the *S*s, and the task operations involved

SUMMARY

The present experiment has studied individual differences in the effects of distraction and interference on cognitive performance as a function of cognitive organization The concept of "cognitive interference" stress was developed and integrated with the model of psychological stress of Lazarus and Baker (**10**), which emphasizes motive thwarting and the arousal of affect The central proposition of the present paper is that cognitive subsystems have an inherent tendency to maintain their organizations Two experimental hypotheses were derived from this proposition (*a*) the stronger the tendency of a cognitive subsystem to maintain its organization, the less vulnerable to distraction are task performances involving that subsystem, and (*b*) when two cognitive subsystems compete, the stronger subsystem tends to dominate cognition such that the *S* tends to emphasize cognitive operations associated with that subsystem

The relative strengths of "conceptual" and "sensorimotor" cognitive subsystems were inferred from the Stroop Color Word Interference Test The origin of this inference resides in previous research by Stroop (**23**, **24**), Ligon (**15**), and the present writers (**11**, **13**), and is based upon the relationship of the speed of naming colors to the speed of reading the names of colors *S*s with a relatively large difference in the two speeds were classified as conceptually oriented, while *S*s with a relatively small difference in the two speeds were identified as sensorimotor oriented These groups were used in two subsequent experimental situations testing the above hypotheses

The first experimental hypothesis was tested by comparing the speed of solving addition problems (a relatively conceptual task)

under neutral and distracting conditions While the two groups of *S*s did not differ significantly in performance under the neutral conditions, under distraction the conceptual *S*s showed significantly less impairment than the sensorimotor *S*s

In testing the second experimental hypothesis, the same *S*s were given a conceptual task (addition problems) and a sensorimotor task (serial disjunctive reaction time) to perform simultaneously, so that one interfered with the other The two groups did not significantly differ from each other on either task when performed singly However, under interference conditions the sensorimotor group compared with the conceptual group demonstrated a greater emphasis in performance on the sensorimotor task at the expense of the conceptual task, while the conceptual group allowed the sensorimotor task to suffer in favor of the conceptual task

The results show that distraction stress produces less impairment of performance when the task involves a strong cognitive subsystem within the *S*s, and that cognitive subsystems have directive effects on behavior leading, under interference stress, to an orientation towards cognitive operations associated with the stronger of the competing cognitive subsystems

The implications of these findings for stress experimentation and for concepts such as "stress tolerance" and "distractibility" were briefly discussed

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Manuscript received July 27, 1957

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